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ABSTRACT

An overview of expert systems technology is presented with emphasis on its current and potential applications to the field of learning disabilities. Characteristics of some expert systems, including reasoning procedures, knowledge base content, and rationale and conclusions, are reviewed. Present applications in the diagnosis of learning problems are briefly described, along with two programs specifically designed for learning disabled students: a diagnostic and perscriptive program and a classification program. Future applications are considered in test interpretation, performance monitoring, administrative support (decision making for compliance with P.L. 94-142), and the provision of behavior management advice to teachers. (CL)

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Expert Systems: Implications for the Diagnosis and Treatment of Learning Disabilities

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Abstract

The application of artificial intelligence to the problems of education is a relatively recent endeavor. One of the most promising areas in artificial intelligence is expert systems technology. Some of the characteristics that make expert systems "intelligent" are identified and exemplified. Selected present and potential applications of expert systems to the field of learning disabilities are presented, and examples of some specific expert systems are discussed.

The Application of Expert Systems to the Field of Learning Disabilities

Introduction

The application of computer technology to the field of learning disabilities has taken a variety of forms. The most common applications have been computer-assisted instruction (CAI), computer-managed instruction (CMI), and computer-assisted testing (Hofmeister, 1984). To a large extent these applications represent reasonably well-developed procedures that existed before microcomputers, but had to wait for the widespread availability of microcomputers to achieve their present popularity. Recently we have seen the development of a new computer technology--the expert system.

Expert systems technology is a field within artificial intelligence and is concerned with the use of the computer to capture and disseminate human expertise. Expert systems have been shown to be effective in such fields as medicine, geology, chemistry, engineering, and business. Recently educators have begun to show an interest in expert systems. Much of this early activity has been focused on problems associated with the field of learning disabilities. This article reports on present and potential applications of expert systems technology to the diagnosis and treatment of learning disabilities.

Overview of Expert Systems

"Knowledge engineering" and "expert systems." "Knowledge engineering" is the term often used to describe the entire process of capturing human expertise, developing a problem-

solving framework, and eventually making the knowledge available to others through a computer-based expert system. The expert system usually gathers information from the user in a dialogue format that simulates a consultation with a human expert. Many expert systems are designed to explain their line of reasoning in everyday English rather than computer code.

Reasoning procedures. The expert system's reasoning procedures, sometimes referred to as the "Inference Engine," acts upon the combination of user-supplied information and information in the expert system's knowledge base.

To facilitate the interaction with the inference engine, the knowledge base is organized into rules. These rules have two components: an "if" component and a "then" component. When the conditions in the "if" component of the rule match the conditions in the user's problem description, a conclusion in the "then" component of the rule is invoked. The following is an "if-then" rule taken from MYCIN, a medical expert system.

Rule 27

If (1) the gram stain of the organism is gram negative, and
(2) the morphology of the organism is rod, and
(3) the aerobicity of the organism is anaerobic,

Then There is suggestive evidence (.7) that the identity of the organism is bacteroides.

Knowledge base content. A knowledge base is built on two types of knowledge: factual and heuristic. Factual knowledge consists of information that can be documented, such as state and

federal regulations and proven hypotheses (Feigenbaum & McCorduck, 1983). Heuristic knowledge captures the "rule of thumb" experiences of humans. In special education such knowledge might come from expert diagnosticians or instructors.

The process of developing a knowledge base is a major activity of considerable value in its own right. Sleeman and Brown (1982), in discussing the need to develop "intelligent" tutoring systems, noted that

> Much remains to be discovered and made explicit. We hope that educational theorists will find the explicit formulation of tutoring, explanation and diagnostic processes inherent in intelligent tutoring systems a test bed for developing more precise theories of teaching and learning. (p. 9)

Rationale and conclusions. During an expert system consultation, the user can ask why a question is being presented by the expert system. The following dialogue is from CLASS.LD2 (Ferrara & Hofmeister, 1984), an expert system that will be presented in more detail in following sections of this article. The expert system asks:

> Does the child have a learning deficit in one or more of the following areas:
>
> listening comprehension
>
> written expression
>
> basic reading skills
>
> reading comprehension
>
> mathematics?

Rather than respond "yes" or "no", the user could ask, "why". The expert system would then respond: "An answer to this question will aid in determining if the child's deficit(s) are in an area which qualifies the child as 'learning disabled' under federal regulations."

An expert system may include a "show" feature that provides a list of the information obtained up to that point in the consultation. A "tracing" function is often available to display information that documents the problem-solving process used in reaching a conclusion.

Incomplete information and certainty factors. A consultation may continue even when information requested by the expert system is incomplete. When the user responds "unknown" to a specific question, the program may note the response and continue with the consultation.

If the expert system determines that missing information is valuable, the certainty associated with any conclusions will be reduced. Because many expert systems are used in areas which deal with conclusions that are rarely definite, "certainty-computing" procedures are necessary. Certainty factors are usually based on a scale of 0-100. A certainty factor of 30 would indicate a relatively low level of confidence in the outcome, whereas a certainty factor of 80 indicates a relatively high level of confidence. The following is an example of an outcome and an associated confidence factor from CLASS.LD2: "Based on the information provided, this child can be classified as learning disabled with a certainty factor of 90."

The features described above demonstrate the characteristics of some expert systems. Terminology and features will vary among systems; however, most will have provisions for explaining the inference process used in reaching a conclusion.

Present Applications

"Intelligent" Diagnostic Programs

Some of the earliest applications of artificial intelligence to the field of education have been concerned with the issue of diagnosis. In the diagnosis of learning problems, the approaches that have been deemed "intelligent" have been concerned with explaining why a student is making a mistake as opposed to just the identification of specific skill deficits.

One of the first and most substantial examples of an intelligent diagnostic program was BUGGY (Brown & Burton, 1980). BUGGY diagnosed learning problems in terms of the underlying "bugs" or consistent computational errors. An example of a bug would be, "When borrowing into a column whose top digit is 1, the student gets 10 instead of 11" (Brown & Burton, 1984). In reporting on findings from one of their field tests, Brown and Burton (1984) reported,

> It is interesting to note that 107 of the 1,325 students tested had a bug in their borrow-from-zero subprocedure and missed 6 of the 15 problems on the test because of this one underlying bug. The characterization given by BUGGY is a much fairer evaluation than scoring these students 60 percent correct. (p. 288)

An interactive videodisc program was developed by Hofmeister (1984) that assessed beginning math skills in English or Spanish and was able to diagnose 27 common bugs. The microcomputer that was linked to the videodisc player analyzed both the correct and the incorrect answers and provided the teacher with a listing of mastered skills from a total possible listing of 335 skills. The program also identified which of the 27 common computational errors were present (Eastmond, 1984).

Expert Systems and Learning Disabilities

While the previously mentioned "intelligent" diagnostic programs clearly have applications to the field of learning disabilities, they were not initially designed to replicate the expertise of an LD specialist. Two programs that were designed as expert systems in the diagnosis and treatment of learning disabilities include a diagnostic and prescriptive program (Colbourn & McLeod, 1983), and a classification program (Hofmeister, 1984).

Diagnosis and prescription. Colbourn and McLeod (1983) developed an expert system to serve as a consultant in the process of diagnosis and prescription. The system was designed to guide the user "through the various stages and levels of diagnosis, from the initial suspicion that a reading problem may exist through to the point at which sufficient information had been gathered to plan an appropriate remedial program" (p. 32). The system's effectiveness was evaluated by comparing its diagnostic reports with those of human diagnosticians. In

summarizing the results of this comparison, Colbourn and McLeod reported that,

> In general, the results of the evaluation were encouraging; the expert system's diagnoses were accurate. Furthermore, because of the system's speed at analyzing error patterns, its diagnostic reports included more information than those of the human diagnosticians. This was particularly noticeable with regard to the analysis of phonic skills. (p. 37)

Classification. One of the most perplexing problems facing special education program administrators in the United States is the misclassification of students as learning disabled. The research findings have indicated that more than half the LD student population may be misclassified (Ysseldyke, 1983; Shepard, Smith, & Vojir, 1983). The major problem is one of overclassification.

Hofmeister (1984) developed an expert system, "CLASS.LD," to provide a second opinion regarding the accuracy of LD placement decisions. Using this program, individuals who make diagnoses of "learning disabled" could check their reasoning and conclusions against decision rules programmed into the computer. Later, Ferrara and Hofmeister (1984) created an updated version of this program, "CLASS.LD2." CLASS.LD2's knowledge base contains over 200 "if-then" rules and produces conclusions with associated certainty factors. With CLASS.LD2, the user can obtain a printed record of the rules used by the computer program and statements regarding how they were applied in reaching a conclusion that a child was or was not learning disabled. The record shows what

questions the computer program presented, the answers the user provided, and the rules the program applied to make "judgments" based upon those answers.

3.0 Future Applications

Hayes-Roth, Waterman, and Lenat (1983) suggest that expert systems may be developed in the areas of prediction, interpretation, diagnosis, remediation, planning, monitoring, and instruction. Several prototype programs are being developed in these areas by staff of the Artificial Intelligence Research and Development Unit at Utah State University. These prototypes are being used to test the feasibility of using expert systems to solve problems in special education.

Intelligent Test Interpretation

One prototype system is the Intelligent Test Interpretation prototype. This expert system provides an individual prescription in the area of mathematics. Results from the Key Math Diagnostic Arithmetic Test (Connolly, Nachtman, & Pritchett, 1976), along with demographic data, will compose most of the information that the user enters. The computer program will use this information and produce a prescription for program planning.

A study that provided an information base for the expert system was conducted by Hofmeister (1984). This study found that Key Math scores correlated .82 with another much more comprehensive criterion-referenced instrument. The knowledge base built into the proposed expert system made use of rules based on correlations between the Key Math instrument and the more

prescriptive but very time-consuming criterion-referenced instrument.

Intelligent Monitoring of Pupil Performance

This prototype expert system was designed to make data-based instructional decisions within the context of a computer-managed instruction (CMI) mathematics program. The CMI program also generated personalized worksheets as well as performing the normal prescription and monitoring activities of a CMI program. The expert system provides teachers with advice on instructional practices as they implement the prescriptions generated by the CMI program.

Teachers input pupil performance data and receive carefully analyzed recommendations for daily lesson planning. Some of the variables the expert system considers include number of problems worked, number of correct responses, number of incorrect responses, number of trials, and rate of performance information.

The expert system monitors student progress and provides advice about moving to new objectives when students have achieved mastery. In addition, the expert system suggests alternative instructional procedures for students who exhibit static patterns in learning.

Intelligent Administrative Support Program

"Mandate Consultant" is a third prototype knowledge-based expert system being developed. This expert system emulates the decision-making processes of a human expert familiar with federal and state regulations dealing with the Education of All

Handicapped Children Act. This expert system provides school officials and parent advocates with expert advice as they attempt to plan and implement instructional programs. The advice identifies the extent to which planning and instructional procedures are consistant with federal and state regulations.

Mandate Consultant holds potential for addressing many of the issues currently resolved at a due process hearing level. Typical issues include categorization, extent of services, and placement decisions for handicapped children. At this time the primary application of this expert system is in the training of administrators and hearing officers rather than its use as a field consultant.

Classroom Behavior Consultant

This prototype expert system was designed to provide behavior management advice to teachers. The user provides information on the type of problem and the conditions under which the behavior usually occurs. The knowledge base rules are organized into three groups. One set of rules elicits information from the user and clarifies the type of behavior problem. The second set of rules then determines the cause of the problem or the factors associated with the maintenance of the problem. The third set of rules then generates recommendations on the intervention procedures that should be successful in treating the problem.

In its prototype form the classroom behavior consultant contains some 600 rules and runs on a powerful microcomputer. It

is anticipated that a larger final version will use more than 1,000 rules and require a minicomputer.

Summary and Conclusions

Recent efforts to apply expert systems to the problems of the field of learning disabilities represent a very different approach to traditional computer applications such as CAI and CMI. Considerable research is needed before any firm conclusions can be reached regarding the value of expert systems for the identification and treatment of learning disabilities. There are, however, some preliminary findings that indicate that this line of research is warranted.

1. Evaluations conducted with prototypes indicate that these systems can perform as well as humans in specific areas.

2. Some of the problems faced by special educators are similar to the problems faced in other disciplines where expert systems have been successful.

3. The process of assembling and organizing knowledge bases for expert systems is a productive activity in its own right. The development of the "if-then" rules of a knowledge base clarifies existing knowledge and identifies areas where knowledge is needed.

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